CLAIMS

What is claimed is:

1. A method of making a semiconductor device having a composite dielectric layer, comprising:

providing a semiconductor substrate;

depositing on the semiconductor substrate alternating sub-layers of a first dielectric material and a second dielectric material to form a layered dielectric structure having at least two sub-layers of the first dielectric material and at least one sub-layer of the second dielectric material,

wherein the first dielectric material is a high-K dielectric material and the second dielectric material is a standard-K dielectric material, and at least one of the one or more dielectric material sub-layers contain nitrogen implanted therein using a nitridation step; and

annealing the layered dielectric structure at an elevated temperature to form a composite dielectric layer about the boundary of each first dielectric material layer/second dielectric material layer.

2. The method of claim 1, wherein the standard-K dielectric material comprises at least one of silicon dioxide, silicon oxynitride, silicon nitride, and silicon-rich silicon nitride.

3. The method of claim 2, wherein during the step of annealing, the first dielectric material and the second dielectric material form a silicon-containing reaction product in at least one of the composite dielectric layers.

4. The method of claim 2, wherein at least one of the composite dielectric layers comprise a silicate.

5. The method of claim 3, wherein the reaction product comprises a metal atom, a silicon atom and at least one of an oxygen atom or a nitrogen atom.

6. The method of claim 1, wherein the high-K dielectric material comprises at least one of hafnium oxide, zirconium oxide, tantalum oxide, titanium dioxide, cesium oxide, lanthanum oxide, tungsten oxide, yttrium oxide, bismuth silicon oxide ($Bi_4Si_2O_{12}$), barium strontium oxide ($Ba_{1-x}Sr_xO_3$), BST ($Ba_{1-x}Sr_xTiO_3$), PZN ($PbZn_xNb_{1-x}O_3$), PZT ($PbZr_xTi_{1-x}O_3$) and PST ($PbSc_xTa_{1-x}O_3$).

7. The method of claim 1, wherein each one composite dielectric layer comprises at least a portion of the sub-layers of the first dielectric material and the second dielectric material, separated by a sub-layer of a reaction product of the first dielectric material and the second dielectric material.

8. The method of claim 1, wherein each composite dielectric layer comprises a substantially uniform layer of a reaction product of the first dielectric material and the second dielectric material.

9. The method of claim 1, wherein thicknesses of the sub-layers is selected to control ratios of metal to silicon to oxygen in at least one of the composite dielectric layers.

10. A method of making a semiconductor device having a composite dielectric layer, comprising:

providing a semiconductor substrate;

depositing on the semiconductor substrate alternating sub-layers of a first dielectric material and a second dielectric material to form a layered dielectric structure having at least two sub-layers of the first dielectric material and at two sub-layers of the second dielectric material,

wherein the first dielectric material is a standard-K dielectric material and the second dielectric material is a high-K dielectric material, and at least one of dielectric material sub-layers contain nitrogen implanted therein using a nitridation step; and

annealing the layered dielectric structure at an elevated temperature to form a composite dielectric layer about the boundary of each first dielectric material layer/second dielectric material layer.

11. The method of claim 10, wherein the standard-K dielectric material comprises at least one of silicon dioxide, silicon oxynitride, silicon nitride, and silicon-rich silicon nitride.

12. The method of claim 11, wherein during the step of annealing, the first dielectric material and the second dielectric material form a silicon-containing reaction product in at least one of the composite dielectric layers.

13. The method of claim 11, wherein at least one of the composite dielectric layers comprise a silicate.

14. The method of claim 12, wherein the reaction product comprises a metal atom, a silicon atom and at least one of an oxygen atom or a nitrogen atom.

15. The method of claim 10, wherein the high-K dielectric material comprises at least one of hafnium oxide, zirconium oxide, tantalum oxide, titanium dioxide, cesium oxide, lanthanum oxide, tungsten oxide, yttrium oxide, bismuth silicon oxide ($Bi_4Si_2O_{12}$), barium strontium oxide ($Ba_{1-x}Sr_xO_3$), BST ($Ba_{1-x}Sr_xTiO_3$), PZN ($PbZn_xNb_{1-x}O_3$), PZT ($PbZr_xTi_{1-x}O_3$) and PST ($PbSc_xTa_{1-x}O_3$).

16. The method of claim 10, wherein each one composite dielectric layer comprises at least a portion of the sub-layers of the first dielectric material and the second dielectric material, separated by a sub-layer of a reaction product of the first dielectric material and the second dielectric material.

17. The method of claim 10, wherein each composite dielectric layer comprises a substantially uniform layer of a reaction product of the first dielectric material and the second dielectric material.

18. The method of claim 10, wherein thicknesses of the sub-layers is selected to control ratios of metal to silicon to oxygen in at least one of the composite dielectric layers.

19. The method of claim 10, wherein the at least two dielectric material sub-layers contain nitrogen implanted therein using a nitridation step.

20. A method of making a semiconductor device having a composite dielectric layer, comprising:

providing a semiconductor substrate;

subjecting the semiconductor substrate to a nitridation step to produce a layer of standard-K dielectric material in the upper portion of one side of the semiconductor substrate;

depositing on the standard-K dielectric side of the semiconductor substrate alternating sub-layers of a first dielectric material and a second dielectric material to form a layered dielectric structure having at least one sub-layer of the first dielectric material and at least one sub-layer of the second dielectric material,

wherein the first dielectric material is a high-K dielectric material and the second dielectric material is a standard-K dielectric material, and at least one of the one or more dielectric material sub-layers contain nitrogen implanted therein using a nitridation step; and

annealing the layered dielectric structure at an elevated temperature to form a composite dielectric layer about the boundary of each first dielectric material layer/second dielectric material layer.